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DEVELOPMENT AND TESTING OF A LEAN SIMULATION TO ILLUSTRATE KEY PRINCIPLES OF TARGET VALUE DESIGN: A FIRST RUN STUDY

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ABSTRACT

Target Value Design (TVD) is increasingly being used for Lean-Integrated Project Delivery processes—especially in the healthcare facility sector. However, the basic principles of TVD take time to comprehend and can seem daunting when implemented for the first time on actual projects. The QUESTION this research sought to address is: Can basic principles of TVD be effectively taught via a relatively simple and brief simulation? The PURPOSE of this research was to develop and test a new simulation that would clearly illustrate basic principles of TVD. The RESEARCH METHOD used for this paper was the iterative development and testing a simplified simulation that modified and extended the "marshmallow challenge" game developed by Peter Skillman. The TVD simulation was tested by construction science students and design professionals in the US and Nepal. FINDINGS suggested the simulation offers an effective way to convey basic TVD principles such as Estimated Cost, Market Cost, Allowable Cost, and Target Cost, and designing to these parameters. The research had some LIMITATIONS, namely that it primarily addressed functional issues as criteria for design success and did not engage all aspects of TVD processes commonly used, such as A3 development, set-based design, or decision-making using *Choosing by Advantages*. However, the IMPLICATIONS and VALUE of this work are that the simulation appears to offer a simple, enjoyable, and effective way to introduce basic TVD principles and their impact to stakeholders who are engaging in the practice for the first time.

KEYWORDS: Lean Simulation; Target Value Design; target cost; Integrated Project Delivery; Marshmallow TVD Simulation

INTRODUCTION

Capital projects are expensive. To make them more affordable, Target Value Design exercises have been incorporated into Lean-Integrated Project Delivery processes during the past decade. The St. Olaf Field House served as a pilot project in target costing (Ballard

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and Reiser 2004). Although target costing (Ansari et al. 1997; Clifton et al. 2004; Cooper and Slagmulder 1997) originally shared some of the spirit and methods of value engineering (Dell'Isola 1973), Sutter Health in California shifted the focus for target costing from that of cost reduction to one of value creation, and began testing and systematizing target costing procedures in earnest on their San-Francisco-based Cathedral Hill project (Ballard and Rybkowski 2009; Denerolle, S. 2013, Rybkowski 2009). The Sutter Health team re-christened the process as Target Value Design (TVD), meaning that in addition to plotting a progressive reduction in a project's estimated capital cost, a TVD team also began incorporating decision-making tools to help stakeholders maximize value for the facility owner. Tools of choice for TVD practitioners include co-location, A3s, Suhr's *Choosing by Advantages* (Suhr 1999), and full scale cardboard mock-ups especially for healthcare facility projects. A statistical analysis has shown that capital projects delivered by TVD cost 15-20% less than traditionally delivered projects (Do 2004).

Use of TVD has spread since the original Sutter Health TVD initiative. However, the challenge of TVD is that its methods are still relatively unfamiliar to stakeholders, especially those accustomed to more traditional project delivery methods such as design-bid-build. Additionally, stakeholders brought onboard a project in mid-stream need to grasp quickly the culture and tools of the Target Value Design process. This need was the primary motivation behind the research of Munankami (2012) who developed and tested the simulation on participants in a first-run study. The simulation has been come to be known by a moniker: *The Marshmallow TVD Simulation.*

THE TARGET VALUE DESIGN FRAMEWORK

The Marshmallow TVD Simulation was developed to help participants intellectually grasp a simplified, conceptual framework of TVD as shown in **Figure 1.**

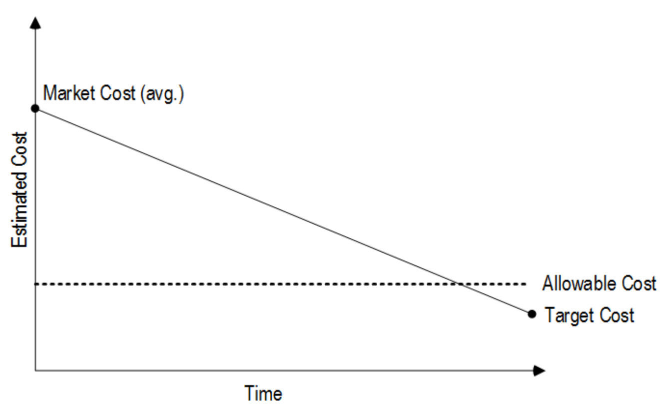

Figure 1. Key longitudinal costing milestones of TVD. *Source:* Adapted from Rybkowski (2009; p. 131, Fig. 47)

The horizontal axis represents time and the vertical axis represents estimated cost. During validation, a *market (or validated) cost* is first estimated, establishing a benchmark against which to measure future cost savings. *Allowable cost* represents that which the owner can pay and still generate a financially viable project. A co-located project delivery team must extract waste from the project using iterative design such that the estimated cost of the project does not exceed *allowable cost*. If allowable cost cannot be reached, the project is shelved. Below the allowable cost is the *Target Cost*. Unlike allowable cost which represents a critical "go-no go" project goal, target cost represents a stretch goal which is desirable to reach though not absolutely essential, thus permitting different ways to contractually create incentives for the team. A flow chart of the TVD process is represented in Ballard (2008, figure 5, pg. 8). Macomber et al. (2005; 2008) proposed seven and then nine foundational practices for Target Value Design. In 2009 and 2011, Ballard published a benchmark and update on tested TVD processes.

To motivate collaborative decision-making by stakeholders and permit funds to flow across traditional disciplinary boundaries, TVD projects often adopt two distinct compensation frameworks, one to carry design between market cost and allowable cost ("pain-sharing"), and other to carry it between allowable cost and target cost ("gain-sharing"). The pain-sharing portion of TVD exercises demands a sharing of risk: participating stakeholders place all profit in an "at risk pool," paid to them only if allowable cost is reached. In return, the building owner commits to paying all direct costs related to development of the design even if the construction is shelved. Once allowable cost is reached, profits are released to participating stakeholders and the rules transition to a "gain-sharing" phase. During gain-sharing, additional cost savings are divided between the owner and participating stakeholders, where the percent share allocated to the participating stakeholders successively increases according to pre-established guidelines (Lichtig 2006; Matthews and Howell 2005; Rybkowski 2009).

The MacLeamy Curve (AIA 2007; MSA 2004) conceptually illustrates how cost of design changes increase over time as a project's development progresses; however ability to impact cost and function happens early. In traditional project delivery, key stakeholders arrive too late to impact change. By contrast, in an integrated project delivery system, stakeholders are involved earlier in the process and have the ability to impact cost. The intent of integrated project delivery is that cost reduction comes not with cheapened design, but rather by extracting wasteful practices from the process. Perhaps unsurprisingly, Integrated Project Delivery has been gaining a following (Bard 2010; Burkhalter 2011; Carbasho 2008).

SIMULATION DEVELOPMENT

Instructions for Play

Stakeholders introduced to TVD for the first time may be unfamiliar with both the process and terms used. Playing live simulations introduces clarity; it facilitates an experiential "lightbulb moment" among stakeholders that is often more vivid than an instructional lecture alone (Boersema 2011, Rybkowski and Kahler 2014; Rybkowski et al. 2008; 2012; Sacks et al. 2007; Smith and Rybkowski 2013; Tommelein et al. 1999; Verma 2003). The TVD simulation developed by Munankami (2012) builds on Peter Skillman and Tom Wujec's *Marshmallow Challenge* (Skillman 2006; Wujec 2015). Two versions of this simulation were developed: (a) a **50-minute** version that primarily illustrates the basics of collaborative cost savings using TVD, and (b) an extended **1-hour-20-minute** version that not only illustrates the basics of collaborative cost savings using TVD, it also introduces participants to the value of integrated processes over traditional processes. The durations for the simulations align with those of typical US-based university class periods.

During both versions, the facilitator projects a spreadsheet of costs onto a wall. Participants are introduced to the concepts of Estimated Cost, Market Cost, Allowable Cost, and Target Cost as shown in Figure 1.

Materials required

In both versions of the game, the following materials are required: masking tape, bamboo skewers, drinking straws, uncooked spaghetti, coffee stirrers, and marshmallows (**Figure 2**). Also needed are a two-foot-long ruler (approx. 60 cm), tables for the teams on which to construct towers, pencils, erasers, pencil sharpeners, paper, a laptop computer (or equivalent) and projector to facilitate display of a costing sheet as well as a spreadsheet.

Figure 2. Materials required for simulation (Munakami 2012)

50-MINUTE VERSION

This version of the developed TVD simulation requires teams of 3-5 participants each to build a table-top tower with a marshmallow on top in two 15-20 minute rounds. The facilitator instructs all teams: "The Owner wishes to design and build a tower that is 2 feet tall (approx. 60 cm), that is capable of holding a marshmallow at the top, and that is no more than 2 inches out-of-plumb. The tower must be constructed with supplied materials and must be free-standing (i.e. cannot be taped to a table)."

During the *Round I*, market cost is established. The teams collaboratively construct the tower without regard for cost during the design process. Cost is calculated only after the tower is complete and teams are given access to a costing sheet (**Figure 3**). Before Round II, market cost is calculated as the average cost of all towers constructed during Round I. Allowable Cost is determined to be 20% lower than the market cost. Target Cost is then the average declared by individual teams as a stretch goal and should be lower than the allowable cost (**Figure 5**). During *Round II*, teams will again develop and construct a tower, but this time will have the costing sheet available while they design the tower with the target cost as their goal. Final costs are tabulated after towers are complete. The facilitator enters numbers onto a projected (pre-formulated) spreadsheet for all to see. The facilitator leads participants in a discussion about the process.

Item	Unit cost	Number of units	Subtotal
Spaghetti sticks	$1.00		
Coffee stirrers	$5.00		
Drinking straws	$2.00		
Bamboo skewers	$3.00		
Masking tape (per joint)	$0.50		
Profit (10%)			
		Total Cost:	

Figure 3. Costing sheet

ONE-HOUR-20-MINUTE VERSION

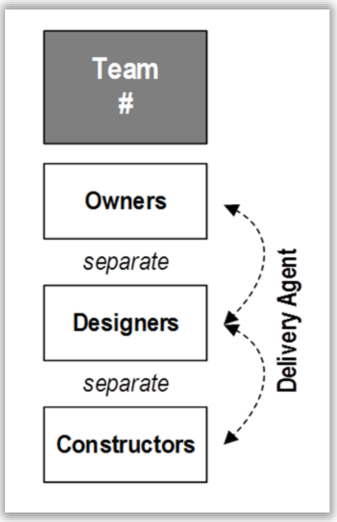

Figure 4.

This version of the simulation is similar to the 50-minute simulation, but allows stakeholders to also experience outcome differences between a linear, silo-ed delivery process and an integrated, co-located, TVD delivery process. Tallies of costs onto a project spreadsheet are made similar to the 50-minute version of the simulation. The main difference is that during *Round I* (linear delivery) teams of 4-6 players representing owners, designers, constructors, and a delivery agent, design and construct the described marshmallow-topped tower while physically isolated in separate rooms or spaces; their communication is restricted to sketching and writing (**Figure 4**). In this version, team members are also given the costing sheet at the beginning of the round and instructed to minimize cost as much as possible, though no costing goals are specified. This setup is intended to simulate a traditional process such as Design-Bid-Build (DBB). The delivery agent carries design sketches, RFIs (Requests for Information) and COs (Change Orders) between isolated team members. This round takes approximately 40 minutes to complete. Note that not only tower costs should be calculated after the round, but numbers of RFIs and COs, and time to complete the exercise should also be tallied. During *Round II* (integrated delivery) stakeholders are brought together into the same room to develop a design through co-location. This is intended to simulate a Lean-Integrated Project Delivery process. This round takes 15-20 minutes to complete. Again the number of RFIs and COs, and time to complete should be added to the spreadsheet for comparison with Round I. Numbers of RFIs and COs should be zero for Round II of course since the team is fully co-located.

Note that for the 50-minute simulation the independent variable (e.g. modification from control group) is the *presence of the costing sheet during design* (the sheet is not present during Round 1 whereas it is present during Round 2). However, during the 1-hour-20 minute simulation, the independent variable is *co-location* (team members are silo-ized during Round 1 whereas team members are co-located during Round 2). Dependent variables are metrics collected. Both versions illustrate TVD but invite different "light bulb moments" and levels of facilitated discussion.

Post-Simulation Discussion

Once all rounds have been completed, the facilitator invites discussion guided by the following questions: (a) What were some basic differences between two rounds? (b) How did the decision-making processes differ between the two rounds? (c) Which round was more stressful to you? (d) Which round offered better cooperation? (e) In which real life circumstances might Round 1 be more appropriate? How about Round 2? (f) What types of contractual arrangements and policies do you think would motivate better performance if Round 2 were an actual project? (g) How might these process be applied to your real life projects? Because the simulation is intended to enhance understanding of TVD-IPD before being implemented on an actual project, the facilitator should then transition to a different discussion following play, linking lessons learned from the simulation to actual TVD case study projects (Denerolle 2013; Do et al. 2014; Rybkowski 2009).

ROUND I: Establish Market Cost, Allowable Cost, and Target Cost

		TEAM A		TEAM B		TEAM C		TEAM D		TEAM E	
	Unit cost	No. of units	Subtotal	No. of units		No. of units		No. of units		No. of units	
Spaghetti sticks	$1.00	3	$3.00	6	$6.00	9	$9.00	0	$0.00	4	$4.00
Coffee Stirrers	$5.00	21	$105.00	1	$5.00	11	$55.00	8	$40.00	8	$40.00
Drinking straws	$2.00	30	$60.00	12	$24.00	5	$10.00	24	$48.00	16	$32.00
Bamboo skewers	$3.00	16	$48.00	15	$45.00	2	$6.00	8	$24.00	4	$12.00
Masking tape (per join	$0.50	17	$8.50	9	$4.50	3	$1.50	8	$4.00	8	$4.00
Subtotal			$224.50		$84.50		$81.50		$116.00		$92.00
Profit (10%)			$22.45		$8.45		$8.15		$11.60		$9.20
TOTAL			$246.95		$92.95		$89.65		$127.60		$101.20

Establish Target Cost

Market Cost Cost (= average of all towers)	$131.67					
Allowable Cost (=20% lower than Market co	$105.34					
Teams Declare **Target Cost** preferences	94.31	80	85	70	85	
TARGET COST	82.86	(=average of all declared TCs)				

ROUND 2: Design to Target Cost

		TEAM A		TEAM B		TEAM C		TEAM D		TEAM E	
	Unit cost	No. of units	Subtotal	No. of units		No. of units		No. of units		No. of units	
Spaghetti sticks	$1.00	1	$1.00	4	$4.00	1	$1.00	0	$0.00	4	$4.00
Coffee Stirrers	$5.00	0	$0.00	0	$0.00	6	$30.00	0	$0.00	4	$20.00
Drinking straws	$2.00	3	$6.00	12	$24.00	3	$6.00	6	$12.00	2	$4.00
Bamboo skewers	$3.00	9	$27.00	9	$27.00	6	$18.00	8	$24.00	4	$12.00
Masking tape (per join	$0.50	13	$6.50	0	$0.00	1	$0.50	4	$2.00	4	$2.00
Subtotal			$40.50		$55.00		$55.50		$38.00		$42.00
Profit (10%)			$4.05		$5.50		$5.55		$3.80		$4.20
TOTAL			$44.55		$60.50		$61.05		$41.80		$46.20

Figure 5. Spreadsheet for tabulation of tower costs after Rounds I and II.

SIMULATION TESTING

To test the effectiveness of the developed TVD simulation, 24 design students and 24 professionals were recruited to test a first-run study of the 1-hour-20 minute version of the simulation. The students were from the Acme Engineering College, Department of Architecture, Purbanchal University in Kathmandu, Nepal. (**Figures 6, 7**).

Post-play Questionnaire

Following play, participants were asked to complete a questionnaire about their experience playing the simulation using a Likert scale, where 1 represented “not effective at all” and 5 represented “very effective” with respect to the effectiveness of the simulation in explaining the following: (A) mutual respect and trust; (B) mutual benefit and reward; (C) Collaborative innovation and decision-making; (D) early involvement of key partners; (E) early goal definition, (F) intensified planning; (G) open communication, (H) appropriate technology, (I) organization and leadership. They were also asked to define their understanding of Market Cost, Allowable Cost, and Target Cost, in their own words.

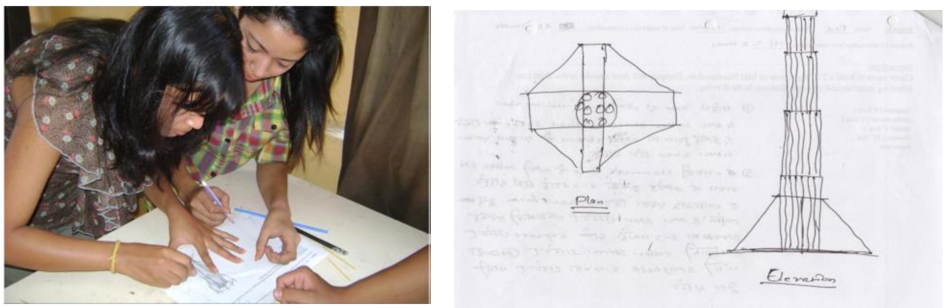

Figure 6. *Round One:* Separation of owners, designers and constructors communicated through sketches, requests for information, and change orders (Munankami 2012).

Figure 7. *Round Two*: Once target cost was established, teams co-located and worked collaboratively to re-design the tower to meet target cost (Munankami 2012).

Results from Questionnaire

Graphed results from questionnaire responses are shown in **Figure 8**. A histogram and box and whisker plot suggest the game was most successful in items G (intensified planning), C (collaborative innovation and decision-making), and D (early involvement of key partners), and least successful in item E (early goal definition). However, it must be acknowledged that this represented a first run study and that the simulation requires additional testing. There was also the possibility of respondent bias because most participants knew the facilitator well as he was a graduate of the tested university.

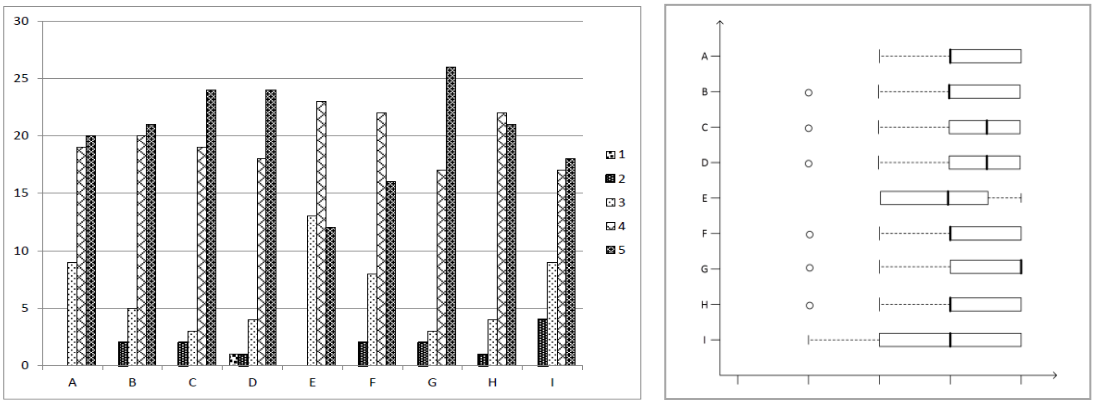

Figure 8. Tabulation of results from questionnaire following first-run study testing of TVD simulation (Munankami 2012).

DISCUSSION

The Marshmallow TVD simulation developed by Munankami (2012) has been played and tested since 2013 at Texas A&M University's Department of Construction Science courses in Lean Construction; in 2014 by Carolina Asensio Oliva, University of Campinas, Brazil; at the 2015 Associated Schools of Construction Conference, College Station, TX; and by lean consultant, Tobias Guller of *Lean Ingenieure* in Germany who requested instructions from our laboratory and has since translated the simulation instructions into the German language. In 2015, Paul Ebbs (2015) reached out to our laboratory for instructions, which we sent, and described on his blog successfully implementing the simulation at a Boise State University workshop to prepare 30 practicing professionals for application of TVD on an actual project. Those who have administered the simulation as lean consultants or in classrooms have shared feedback with the first author and have made some adaptations to suit the needs of their local constituencies. While most who have administered the simulation report it effectively illustrates and teaches TVD, some have expressed concern that the second round of the simulation demonstrated a trending of design quality toward minimalism as cost was reduced. This is a legitimate concern and suggests opportunities to modify the simulation to also include aesthetic delineators as criteria for success.

CONCLUSION

The main objective of the TVD Marshmallow Simulation has been to help participants understand basic principles of Target Value Design (TVD) within Lean-Integrated Project Delivery (Lean-IPD) process. Two versions of the game were developed: a shorter 50-minute version and a longer 1hr-20-minute version. Initial feedback from those who have administered the simulation has been thus far positive. The simulation is already being used by lean consultants and educators at various locations worldwide. Just as with the spirit of Lean, the simulation is under continuous adaptation and improvement. Ideally the simulation should be systematically tested before TVD implementation on an actual project. However, the observation that it already has developed "a life of its own" offers some indication of its effectiveness as a way to introduce Target Value Design.

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